Appendix C

Spatial Analysis Precipitation Tools

Overall Function: This appendix describes the tools that should be provided in DDAP to analyze how precipitation typically varies over the Basin both spatially and from one time of the year to another. The results will vary depending on the historical period of record and how the results are interpreted by the user performing the analysis, thus a PETA must be selected prior to using these tools.

PETA Selection:

When the Spatial Precipitation category is chosen, the user should first be given a list of PETAs that exist for the Basin. The user will then choose the appropriate PETA. How the tools are applied will also depend on whether the HPOR is being analyzed or whether the record is being extended, thus the user will also need to select the period to be worked on from a list of available periods defined for the chosen PETA.

Basic Display: One the PETA and the period of record have been selected, the basic display for the Spatial Precipitation tools window should contain the following in addition to overlay, zoom, query, and units features:

- Basin boundaries - i.e. the overall boundaries of the Basin currently selected as specified in the Basin definition (not Watershed boundaries), and

- All precipitation stations that have been previously selected for use for analyzing precipitation patterns for the Basin and PETA (see Station Selection tool in this appendix).

Menus:

Control and Tools menus should be included. The Control menu only needs a Quit option. The tools menu should contain the following options:

- Station Selection,
- High/Low Elevation Plot,
- Compute Monthly Means,
- Delete Stations,
- Precipitation versus Elevation,
- Isohyetal POR Adjustment,
- Gage/Isohyetal Adjustment,
- Anomaly Map, and
- Correlation Patterns.

Each of the Spatial Precipitation tools are described in this appendix starting on separate pages.

Data Base Considerations:

There appear to be two basic ways to maintain and store the information for each precipitation station used in an analysis. These are:

- Maintain station information (i.e. stations used, consistency corrections, and mean monthly values) separately for each Basin and PETA. This is the way the information is typically handled now. Currently the station information for an analysis for each Basin is not maintained in a data base, but is maintained via program input and output files. When an adjacent Basin or a new analysis is performed for a given Basin, the results from prior analyzes may or may not be examined. There is at least no rigid procedure for examining prior analyzes and then accepting or rejecting the results. This means that a given station that is used for multiple Basins or for several analyses for the same Basin, is more likely to have somewhat different consistency corrections and mean monthly precipitation values for each.

- Maintain a single file for each station that is ever used in any precipitation analysis. The best estimate of any consistency corrections and mean monthly precipitation would be stored. Since mean monthly values are dependent on the HPOR used, sets would have to be maintained for each such period (it is recommended that to the maximum extent possible, the same historical period of record should be used for an entire RFC area). Besides the best estimates, any prior values of these quantities would also need to be kept in the data base file (along with the associated Basin and PETA). Typically the best estimate from a prior analysis would be used for any subsequent analysis unless the user specifically rejected a value and established a new best estimate. This approach would make it less likely that stations would use different consistency corrections and monthly averages from one analysis to another.

  There is a potential problem with this approach regarding consistency corrections. These corrections can be applied on an annual or seasonal basis for a given analysis. The type of corrections (annual or seasonal) and if seasonal, the beginning of winter and summer, could vary from one analysis to another. Previously defined corrections could only be used directly when the type and beginning of the seasons were the same as the prior values. Otherwise the prior values could only be used as a guide.

When describing the Spatial Precipitation tools, it will be assumed that the second approach will be followed. If the first approach is taken, information from prior analyses would only be utilized during a subsequent analysis if the user decides to look it up and use it.

Isohyetal Analyses

In mountainous areas the computation of areal precipitation estimates are based on an isohyetal

analysis. The isohyetal analysis shows how precipitation typically varies over an area spatially and ideally how the spatial variation changes with the seasons. When performing a spatial analysis of precipitation, it is assumed that two types of isohyetal estimates can exist. The first is an isohyetal analysis that was done independently. Typically this will be the PRISM analysis. PRISM results are generally available on a monthly basis and represent the typical precipitation pattern derived from precipitation gage data for a given historical period. The second type is an adjusted isohyetal analysis. A base adjusted analysis can be generated using some of the spatial precipitation tools described in this appendix. This adjusted analysis will correspond to the HPOR and will include adjustments resulting from comparisons of the PRISM values to gage data and water balance considerations. Even though some of the techniques used to adjust the isohyetal patterns are done on an annual or seasonal basis, the resulting adjusted estimates will be monthly values. An additional adjusted isohyetal analysis can be produced for data sparse areas using the Isohyetal Adjustment - Data Sparse Basin tool described in Appendix D. Generally one of these adjusted isohyetal analysis will be subsequently used to obtain average areal estimates of precipitation for the HPOR.

Station Selection

Function: To select the stations with historical precipitation data that should be included in the analysis for the selected Basin, PETA, and period of record.

Modification to the Basic Display: When the Station Selection tool is chosen, the basic Spatial Precipitation tools display is modified to show in addition to the stations previously specified, all other stations with historical precipitation data for the period of record being analyzed that lie within the latitude, longitude box surrounding the Basin. These stations should be in a different color than those already selected (note - any stations not chosen, should be removed from the basic Spatial Analysis Precipitation tools display when the user quits the Station Selection tool).

User Specification: The user selects a station and then after examining the information available for that station using the query function, indicates whether the station should be included for the given Basin and PETA. If the station has data with different reporting intervals, the user can make a separate choice for each interval (currently only daily and hourly reporting stations are used in historical precipitation analyses, however, stations with data at other intervals could be summed to one of these intervals and a new time series created). It may be wise to indicate in some way which stations have been rejected, at least during this session, so that the user knows which stations have already been examined.

The capability should also be provided with the Station Selection tool to merge the records for two or more stations together for use in the analysis. In many cases stations in the NCDC climatological network are moved from one location to another nearby site. In some cases the station identifier is not changed and the move is just reflected in the meta data. In other cases the station is discontinued and a new station established. In many of these cases it is easier to treat the record as a single location with moves than as several different stations.

Output: As the user accepts a given station for use in the analysis, the station, along with a daily or hourly indicator, is added to the list of precipitation stations to be included for the Basin and selected PETA. It should also be noted when the station was added to the analysis, i.e. during the HPOR or a specific extension period. For merged records, the observed data and meta information for each of the original stations should be combined into a single new station (should be clearly identified as a merged record). If there are overlaps in the merged records, the user should designate which original station's data should be used during these periods.

High/Low Elevation Plot

Function: Generates a plot of the relationship between a high and a low elevation station. Used to determine if station weights should be specified on a annual or seasonal basis for mountainous areas. Tool is only valid when working with the HPOR.

User Specification: User selects a high and low elevation station to use.

Method: The average monthly ratio of precipitation at the high elevation site to the low elevation site is computed based on all months during the historical period of record when both stations have complete data. Only observed data are used (not based on monthly means computed using the Compute Station Averages tool).

Display Generated: Plot in the form of Figure 6-3-1 in the Calibration Manual.

Output: Nothing output to the data base.

Compute Monthly Means

Function: To produce mean monthly precipitation values for the HPOR for each station used in a mountainous area analysis for a given Basin and PETA. Also used in mountainous areas to check the consistency of the precipitation records and make any needed corrections.

Method: The basic procedure is that utilized by the current PXPP program (can use IDMA to graphically display double mass plots and interactively make consistency corrections) , however, the input to PXPP and how the results are utilized will depend on whether some of the stations have been involved in a prior analysis (either for another Basin or a different PETA for this Basin) and whether one is working with the HPOR or an extension. When working with the HPOR, the run period for PXPP is the historical period of record. When working with an extension, the run period can begin at or prior to when the extension begins and go through the end of the extension period.

- When working with the HPOR:
  - For stations that have consistency corrections defined from a prior analysis, the currently defined best estimates of these corrections should be used as input to PXPP if the type of correction, annual or seasonal, and if seasonal, the beginning month of each season, are the same. If the type or beginning months differ, then the prior values should only be available as a guide. If the user decides to change a prior correction, the prior values should be maintained with an indication of the prior analyses to which they apply.
  - For stations that have mean monthly precipitation values defined for the same HPOR, the values derived using PXPP should be compared to the established prior best estimates. The user can then decide whether the new values should replace the existing best estimates. If so, the prior values should be maintained as with consistency corrections (there are bound to be some differences in the monthly means derived from each analysis since the base station used will vary as well as the estimator stations).

- When working with an extension to the HPOR (in this case mean values are only being determined for those stations that were not part of the HPOR analysis):
  - For stations that have consistency corrections defined from a prior analysis for the extension period, the currently defined best estimates of these corrections should be used when running PXPP (again dependent on type of correction and beginning months of each season). If the user decides to change any of these corrections, the prior values should be maintained with an indication of the prior analyses to which they apply. Consistency corrections that apply prior to the beginning of the extension period shouldn't be allowed to be changed.
  - Mean monthly values for those stations that were not part of the HPOR analysis are computed by taking the ratio to the base station determined by PXPP and multiplying it by the best estimate of the mean monthly values for the base station for the HPOR. Again, if these stations have mean monthly precipitation values defined for the same HPOR from a prior analysis, the values derived using PXPP should be compared to the established prior best estimates. The user can then decide whether the new values should

replace the existing best estimates. For all stations that were part of the HPOR analysis, the mean monthly values can't be changed when running an extension period.

User Specifications:

- Beginning of the PXPP run if an extension period,
- Station to be used as the base station (for an extension period PXPP run, the base station must have mean monthly values defined for the HPOR),
- Indicator as to whether precipitation is to analyzed on a annual or seasonal basis and if so, the first month of winter and summer for computing seasonal amounts - defaults are previously defined values for the PETA- values can only be changed for a HPOR run,
- Indicator as to whether consistency checks are to be made (yes or no),
- If consistency check option 'on', indicator as to whether plots are annual or seasonal and if so, the first month of winter and summer for making consistency checks and corrections - defaults are previously defined PETA values - values can only be changed for a HPOR run,
- Option to display and output precipitation totals for all months for each station - only valid for a HPOR run,
- Option to output correlation information and if so, whether annually or seasonally, and
- Specification of how to group stations on double mass plots (currently a max of 5 stations on a plot).

The indicator as to whether precipitation is to be analyzed on a seasonal basis and the beginning and end of each season are new options for PXPP (decision is based on whether different types of storms predominate at different times of the year (e.g. orographic in the winter and convective in the summer), whereas the seasons for consistency checks are based on when snow predominates versus when rain predominates).

Displays Generated:

- Tabular display similar to current PXPP standard output showing a summary of the program input and a listing for all stations for each month showing the number of cases used, the ratio to the base station, and the derived mean monthly precipitation, plus the mean seasonal and annual precipitation for each station,
- Tabular display of the total precipitation for each month for each station with an indication of whether the value is observed or estimated (only if option to display output monthly precipitation is 'on'),
- Plots of the ratio to base for all stations (form similar to Figure 6-3-1 in the Calibration Manual) - probably no more than 10 stations per plot, and
- Average annual and seasonal amounts plotted on a map.

Output: (when the user Okays the results)

- Seasonal indicators and the beginning of winter and summer whenever seasonal analysis and consistency check indicators are defined for the first time or updated (applies to the entire PETA),
- Derived mean monthly precipitation whenever values are first generated or the user specifies that the current best estimate is to be changed,

• Derived consistency corrections whenever values are first generated or the user specifies that current corrections are to be changed,
• Monthly precipitation totals (observed or estimated) for each month during the HPOR when the option to display and output those values is ‘on’ (only one set stored for a PETA - new values overwrite any prior values),
• Specification of how stations are grouped on double mass plots (latest grouping stored), and
• Correlation information for each station on an annual or seasonal basis if specified by the user (only one set stored for a PETA - new values overwrite any prior values).

Delete Stations

Function: To remove stations previously selected using the Station Selection tool.

User Specification: User selects each station to be removed from the spatial analysis. Stations can only be removed when working with the HPOR.

Output:

- Remove station from list of stations selected for the Basin for specified PETA, and
- Remove any mean monthly values and consistency corrections stored with the station information that are unique to the current Basin and PETA.

Precipitation versus Elevation

Function: To see how precipitation varies with elevation on a annual and seasonal basis for the HPOR.

Input: (all from previously stored information)

- Stations are all those selected for the Basin and PETA using the Station Selection tool,
- Elevations come from the meta data file for each station and are based on the current location of the site,
- Seasonal analysis indicator (annual or seasonal) and if seasonal, the beginning of winter and summer, are the values defined for the PETA using the Compute Monthly Means tool, and
- Mean monthly precipitation values for the HPOR for each station are obtained from the values generated by the Compute Monthly Means tool.

User Specification:

- Indicator to use current best estimate of the mean monthly precipitation for each station or to use the prior estimate for this Basin and PETA if different from the current best estimate, and
- Indicator as to whether seasonal values, if specified, should be shown on the same plot.

Display Generated: Plots of precipitation versus elevation in the form of Figure 6-3-2 in the Calibration Manual. If seasonal plots and winter and summer are on the same plot, each season should be in a different color with a different plot symbol.

Output: Nothing output to the data base.

Isohyetal POR Adjustment

Function: To adjust the base isohyetal maps (typically PRISM) to the HPOR being used for the current analysis.

Input: (all from previously stored information)

- Stations are all those selected for the Basin and PETA using the Station Selection tool that apply to the HPOR,
- Seasonal analysis indicator (annual or seasonal) and if seasonal, the beginning of winter and summer, are the values defined for the PETA using the Compute Monthly Means tool,
- Total precipitation for each month for the HPOR for each station are obtained from the values generated by the Compute Monthly Means tool (output monthly precipitation totals option must have been 'on' for a HPOR run), and
- Mean monthly isohyetal maps from the base analysis and the period of record for the base analysis.

Checks:

- HPOR must overlap the period of record for the base isohyetal analysis, and
- Not valid to use this tool once the isohyetal analysis has been adjusted using the Gage/Isohyetal Comparison tool.

Displays Generated:

- Table showing for each station the mean annual or seasonal precipitation computed from the monthly totals for the HPOR, the same value computed for the period of record for the base isohyetal analysis, and the ratio of the HPOR value to the isohyetal base period value on an annual or seasonal basis. Table should also show the mean ratio and standard deviation for all the stations on an annual or seasonal basis, and
- Annual or seasonal ratios for each station plotted on a map (if seasonal, each on a separate plot).

Adjustment Method: (based on user selection)

- Single ratio applied to the base isohyetal maps (ratio can vary with seasons). The same ratio is applied to all months within the year or season, or
- User drawn iso-ratio lines defining how the adjustment should vary from one part of the Basin to another. Adjustment at any point derived by interpolating between user drawn lines. Again the same adjustment applied to all months within the year or season.

Output: (after user Okays the results)

- Adjusted isohyetal maps for each month - only needs to cover area within the Basin boundary (output even if no adjustment made, i.e. adjustment ratio is 1.0), and
- Indicator that adjusted isohyetal maps exist for the PETA and that a HPOR adjustment has been made.

Gage/Isohyetal Adjustment

Function: Adjust HPOR isohyetal maps based on comparisons with gage data and water balance computations. If an adjustment can't be made for a difference between the HPOR and the period used to derive the base isohyetal maps due to the period for the base maps being at least partly outside the HPOR (see Isohyetal HPOR Adjustment tool), then any adjustment determined with this tool may be partly the result of differences in the periods of record.

Input: (all from previously stored information)

- Stations are all those selected for the Basin and PETA using the Station Selection tool,
- Latitude and longitude come from the meta data file for each station and are based on the current location of the site,
- Seasonal analysis indicator (annual or seasonal) and if seasonal, the beginning of winter and summer, are the values defined for the PETA using the Compute Monthly Means tool,
- Mean monthly precipitation for the HPOR is obtained from the values generated by the Compute Monthly Means tool (warnings printed for any stations that don't have monthly means), and
- Mean monthly isohyetal maps (either adjusted maps previously generated or the base isohyetal maps if adjusted versions don't exist for the Basin and PETA).

Displays Generated:

- Annual or seasonal maps showing the ratio of the precipitation computed from the gage data to the precipitation picked off the isohyetal maps at the location of each station (Watershed boundaries and topography should be shown), and
- Tabular summary listing the gage precipitation, isohyetal amount, and the ratio of gage to isohyetal value for each station on an annual or seasonal basis. Also include the mean of the ratio over all stations and the standard deviation.

Adjustment Method: (based on user selection)

- User drawn iso-ratio lines defining how the adjustment should vary from one part of the Basin to another. Adjustment at any point derived by interpolating between user drawn lines. The same adjustment applied to all months within the year or season, or
- Single ratio applied to the entire Basin area (ratio can vary with seasons). The same ratio is applied to all months within the year or season.

Output: (after user Okays the results)

- Adjusted isohyetal maps for each month - only needs to cover area within the Basin boundary (output even if no adjustment made, i.e. adjustment ratio is 1.0), and
- Indicators that adjusted isohyetal maps exist for the PETA (if not already set to 'on') and that a Gage adjustment has been made.

Anomaly Map

Function: To produce annual or seasonal anomaly maps to aid in the selection of station weights.

Input: (all from previously stored information)

- Stations are all those selected for the Basin and PETA using the Station Selection tool,
- Latitudes, longitudes, and elevations come from the meta data file for each station and are based on the current location of the site,
- Seasonal analysis indicator (annual or seasonal) and if seasonal, the beginning of winter and summer, are the values defined for the PETA using the Compute Monthly Means tool, and
- Mean monthly precipitation for the HPOR is obtained from the values generated by the Compute Monthly Means tool.

Procedural Steps:

- Generate precipitation-elevation plots on an annual or seasonal basis (based on indicator) as produced by the Precipitation versus Elevation tool described in this appendix,
- User specifies average relationship between precipitation and elevation on each plot (linear relationship),
- The difference between the actual precipitation and that obtain from the average precipitation versus elevation relationship based on the elevation of the site is computed for each station on an annual or seasonal basis,
- Differences are plotted on a map along with topography, and
- User can draw equal anomaly lines (optional).

Sample Display: A sample of the form of an anomaly map is shown in Figure 6-3-8 of the Calibration Manual.

Output: Anomaly maps (annual or seasonal) are stored for later reference. Only one version of the maps are retained for a given Basin and PETA (i.e. overwrite previous versions).

Correlation Patterns

Function: To display correlation patterns for any station based on the correlation coefficients stored using the Compute Monthly Means tool described in this appendix.

Input: (all from previously stored information)

- Stations are all those selected for the Basin and PETA using the Station Selection tool,
- Latitudes, longitudes, and elevations come from the meta data file for each station and are based on the current location of the site, and
- Correlation information for each station that was generated by the Compute Monthly Means (only one set of information stored for each Basin and PETA - either annual or seasonal).

User Specification: Select station for which the correlation pattern, annual or seasonal, is to be displayed.

Display Generated: Correlation coefficients for all stations relative to the selected station are plotted on a map on an annual or seasonal basis with topography included (samples of the form of the display are shown in Figures 6-3-6 and 6-3-7 of the Calibration Manual - equal correlation lines are not needed).

Output: None